VIRTUAL INSTRUMENT BASED FAULT DETECTION IN THREE PHASE CIRCUIT

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VIRTUAL INSTRUMENT BASED FAULT DETECTION IN THREE PHASE CIRCUIT

A Thesis Submitted in Partial Fulfilment of the requirement for the Degree of

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CERTIFICATE

This is to certify that the draft thesis entitled "**Virtual Instrument Based Fault Detection in Three Phase Circuit**", submitted to the National Institute of Technology, Rourkela by **Mr. Alok Malik(109EE0279), Mr. Biswabhusan Nayak(109EE0289)** in partial fulfilment of the requirements for the for the award of BACHELOR OF TECHNOLOGY in ELECTRICAL ENGINEERING during session 2012-2013 at National Institute of Technology, Rourkela is a bona fide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

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In my opinion, the draft report/thesis is of standard required for the award of a BACHELOR OF TECHNOLOGY in Electrical Engineering.

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Alok Malik (109EE0279)

Biswabhusan Nayak (109EE0289)

Electrical Engineering

Dedicated to

Our Parents

ABSTRACT

At present the field of science, engineers and technology is so dynamic due to recent improvement in computer and other technologies. The advances in computer field developed such programs to solve our traditional and novel problems of practical life. We can solve our complex problems within a few minutes due to high computational abilities, accuracy of computer based programs. For electrical people there are many software programs are currently used in academia to design and analyse different kinds of electrical circuits and models. The main objectives of this report is to design three phase power system models using the VI modules available **,** and detect the types of of fault like 3-phase (L-L-L), 3-phase to ground (L-L-L-G), Line to Ground(L-G), Line to line(L-L), Line to Line to Ground(L-L-G) in power system . Initially the simulation work is done by using a software based programs named **Multisim**, which is an electronic Schematic Capture and simulation program .After completion of the simulation task the real time three phase hardware circuit interfaces with the **LabVIEW** model to detect the real time faults in power system

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LABVIEW MODEL AND HARDWARE INTERFACING

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ABBREVIATIONS AND ACRONYMS

LG	-	Line to Ground
LL	-	Line to Line
LLG	-	Line to Line to Ground
LLL	-	Line to Line to Line
LLLG	-	Line to Line to Line to Ground
3-ϕ	-	Three phase
VI	-	Virtual Instrument
LED	-	Light Emitting Diode
DAQ	-	Data Acquisition
AC	-	Alternating Current
DC	-	Direct Current
RMS	-	Root Mean Square

CHAPTER #1

Introduction

1.1 INTRODUCTION:

A power system is not static at all & changes during operation (switching ON-OFF of generators and transmission lines) and during planning (addition of generators and transmission lines). Thus fault studies need to be performed periodically by utility engineers (like in the CEB). Faults usually occur in a power system due to insulation failure, flashover, and physical Damage or human error. These faults may either be symmetrical in nature involving all the three phases or may be asymmetrical where usually only one or two phases may be involved. Faults may also occur by either short-circuits to earth or between live conductors, or may be caused due to broken conductors in any one or more phases. Sometimes simultaneous faults may occur which involves both short-circuit and broken conductor fault or open circuit fault. Balanced three phase faults can be analysed using an equivalent single phase circuit. But in case of asymmetrical faults it is quite complex to analyse by taking any one phase into consideration, in that case the use of symmetrical components theory helps to reduce the complexity of the calculations and to analyse the faults. The fault analysis is usually carried out using per-unit quantities (similar to percentage quantities) as they give solutions which are nearly consistent over different voltages and power ratings and operate on values of the order of unity.

In this report the “The Symmetrical Components Theory” plays a vital rule to detect different kinds of faults. For electrical people there are many software programs (Virtual Instruments) are currently used in academic as well as in industry to design and analyse different kinds of complex circuit like PSPICE from Micro Sym Corporation and Mat Lab from Math Works, Multisim and LabVIEW etc. The Symmetrical Component Theory and software program (Multisim and LabVIEW) are used to calculate the symmetrical components and from which fault can be detected.

1.2 SYMMETRICAL COMPONENTS THEORY:

Balanced three phase faults may be analysed using an equivalent single phase circuit. But in case of asymmetrical three phase faults, the use of symmetrical components helps to reduce the complexity of the calculations of transmission lines. In 1918, Dr. C. L. Fortescue wrote a paper entitled “Method of Symmetrical Coordinates Applied to the Solution of Polyphase Networks.”[1]. In that paper Dr. Fortescue described how arbitrary unbalanced 3-phase voltages (or currents) could be transformed into 3 sets of balanced 3-phase components [1]-[2]. He called these components as “symmetrical components.” The paper shows that unbalanced problems can be solved by the resolution of the currents and voltages into certain symmetrical relations.

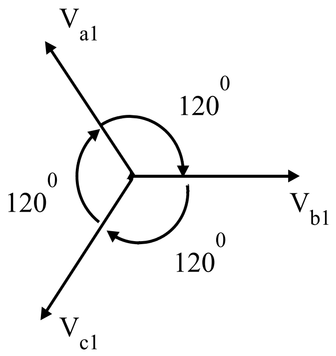

FIGURE 1.1: +VE SEQUENCE COMPONENT

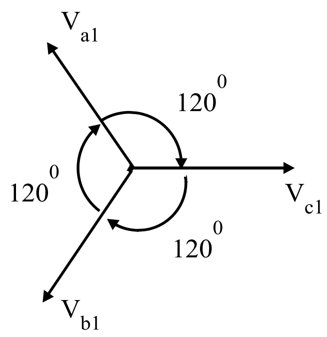

FIGURE 1.2: -VE SEQUENCE COMPONENT

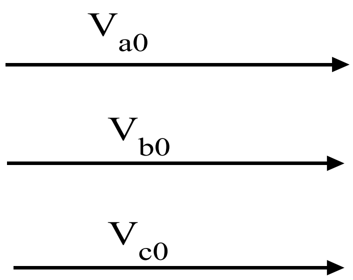

FIGURE 1.3: ZERO SEQUENCE COMPONENT

Positive sequence component:- The positive sequence consists of three phasors equal in magnitude displaced from each other by 120º in phase and having the same phase sequence as the original phasors. The positive sequence is assumed as abc and the subscript is 1.

Phasor Relation: With V_{a1} as the reference phasor the relationship between negative sequence components can be given as-

$$V_{b1} = a^2 V_{a1} \tag{1.1}$$

$$V_{c1} = a V_{a1} \tag{1.2}$$

Negative sequence component:- The negative sequence consists of three phasors equal in magnitude displaced from each other by 120º in phase and having the phase sequence opposite to that of the original phasors. The negative sequence is assumed as acb. The negative sequence subscript is 2.

Phasor Relation: With V_{a2} as the reference phasor, the relationship between negative sequence components can be given as-

$$V_{b2} = a V_{a2} \tag{1.3}$$

$$V_{c2} = a^2 V_{a2} \tag{1.4}$$

Zero sequence components:-The zero sequence consists of three phasors equal in magnitude and with zero phase displacement from each other. The zero sequence subscript is 0.

Phasor Relation: With V_{a0} as the reference phasor, the relationship between negative sequence components can be given as-

$$V_{b0} = V_{a0} \tag{1.5}$$

$$V_{c0} = V_{a0} \tag{1.6}$$

1.3 OPERATOR ‘a’:

When a balanced three phase is considered all phases are separated from each other by an angle of 120^0. In case of complex number system there is an operator j, which has the value $\sqrt{-1}$, it causes rotation of 90^0 in counter clockwise direction to any complex number and has magnitude of 1. Similarly we define another operator ‘a’ which has a magnitude of unity and cause a rotation of 120^0 when operated on any complex number in anti-clockwise direction.

$$a = 0.5+j0.866 = 1\angle 120^0 \tag{1.7}$$

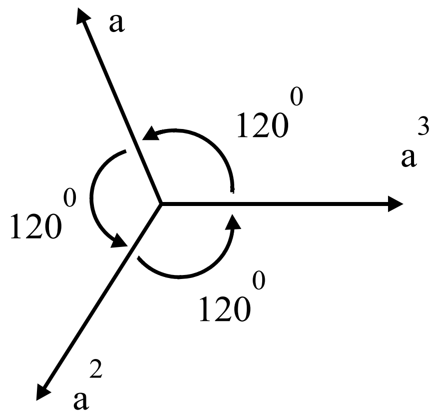

FIGURE 1.4: OPERTOR ‘a’

Properties of ‘a’-

$a^2 = -0.5-j0.866$

$a^3 = 1$

and

$a + a^2 + a^3 = 0$

Relationship between sequence components can be given as:-

$$V_{a0} = V_{b0} = V_{c0} \tag{1.7}$$

$$V_{b1} = a^2 V_{a1} \tag{1.8}$$

$$V_{c1} = a V_{a1} \tag{1.9}$$

$$V_{b2} = aV_{a2} \tag{1.10}$$

$V_{c2} = a^2 V_{a2}$ (1.11)

So we can write now,

$V_a = V_{a0} + V_{a1} + V_{a2}$ (1.12)

$V_b = V_{b0} + V_{b1} + V_{b2} = V_{a0} + a^2 V_{a1} + aV_{a2}$ (1.13)

$V_c = V_{c0} + V_{c1} + V_{c2} = V_{c0} + aV_{a1} + a^2 V_{a2}$ (1.14)

&

$V_{a0} = \frac{1}{3}(V_a + V_b + V_c)$ (1.15)

$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2 V_c)$ (1.16)

$V_{a2} = \frac{1}{3}(V_a + a^2 V_b + aV_c)$ (1.17)

To calculate the sequence components for any unbalanced system the above equations are used. The above equations will be applicable for current also.

CHAPTER #2

Different Types of Faults in Three Phase Circuit and Their Analysis

2.1 TYPES OF FAULTS:

Generally fault in power system is due to over current or short circuit and sometimes due to overload on the supply system. In power system we can observe almost ten types of fault. These faults are Line to Ground (LG), Line to line (LL), Line to Line to Ground (LLG), 3-phase (LLL), 3-phase to ground (LLLG)[8].After all these faults comes under symmetrical and unsymmetrical faults as given in Table [1].

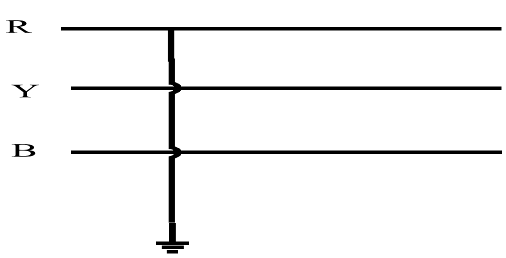

FIGURE 2.1: LG FAULT

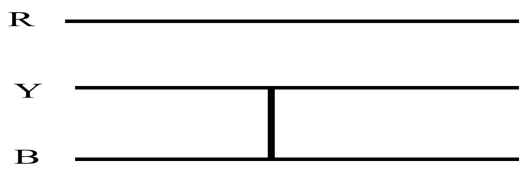

FIGURE 2.2: LL FAULT

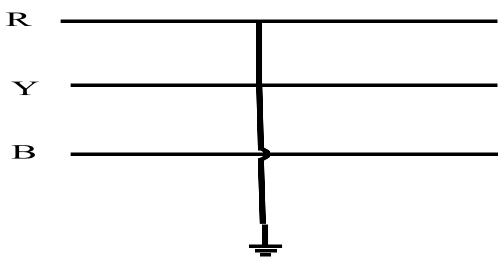

FIGURE 2.3: LLG FAULT

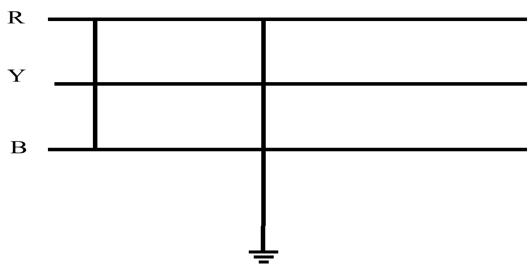

FIGURE 2.4: THREE PHASE FAULT

Out of all types of faults in 3-ϕ circuit L-G fault is most occurring fault (85%) and least severe. In the other hand symmetrical faults are highly severe and percentage of occurrence is less (2%).

TABLE 1.1:-TYPES OF FAULT

Symmetrical fault	Unsymmetrical fault
3-phase (LLL) 3-phase to ground (LLLG)	Line to Ground(LG) Line to line(LL) Line to Line to Ground(LLG)

2.2 SINGLE LINE TO GROUND FAULT:

When there is a short circuit between any power conductor and ground the fault is called as single line to ground (LG) fault. Suppose the fault occurs in phase 'a' of an unloaded alternator [8] :

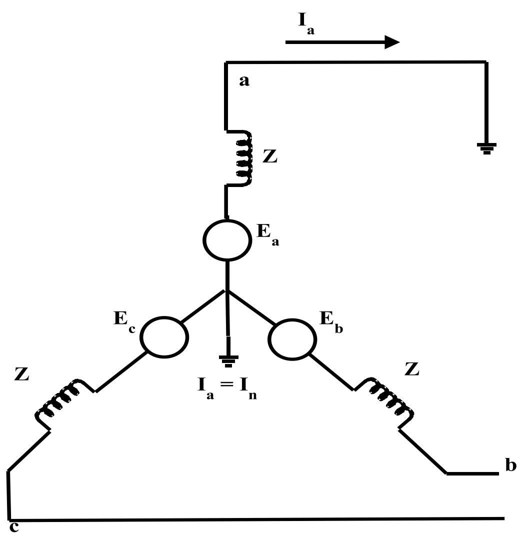

FIGURE 2.5: CIRCUIT DIAGRAM FOR LG FAULT

Fault is in phase a:

$$V_a = 0 \tag{2.1}$$

$$I_b = 0 \tag{2.2}$$

$$I_c = 0 \tag{2.3}$$

$$\begin{pmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{pmatrix} = \frac{1}{3}\begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix}\begin{pmatrix} I_a \\ 0 \\ 0 \end{pmatrix}$$

$I_{a0} = I_{a1} = I_{a2} = I_a / 3$ (2.4)

$V_{a1} = E_a - I_{a1}Z_1$ (2.5)

$V_{a2} = -I_{a2}Z_2$ (2.6)

$V_{a0} = -I_{a0}Z_0$ (2.7)

According to the theory of symmetrical component:

$V_a = V_{a1} + V_{a2} + V_{a0}$

$0 = E_a - I_{a1}(Z_1 + Z_2 + Z_0)$

$I_{a1} = E_a / (Z_1 + Z_2 + Z_0)$ (2.8)

It is clear from the above equations that in case of LG fault all the three sequence components remain present. If we consider the sequence components in terms of current then all are equal in magnitude and phase angle. So the sequence networks should be connected in terms of series .The equivalent sequence network is shown below Fig 2.6.

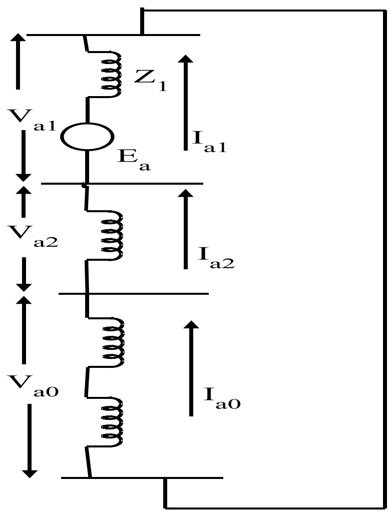

FIGURE 2.6: EQUIVALENT SEQUENCE NETWORK FOR LG FAULT

2.3 DOUBLE LINE TO GROUND FAULT:

If any two phases get short circuit and at the same time both are also shorted with ground as shown in Fig 2.7 then the fault is termed as double line to ground (LLG)fault[8]. Suppose the fault occurs in the phase ‘a’ and ‘b’ of alternator

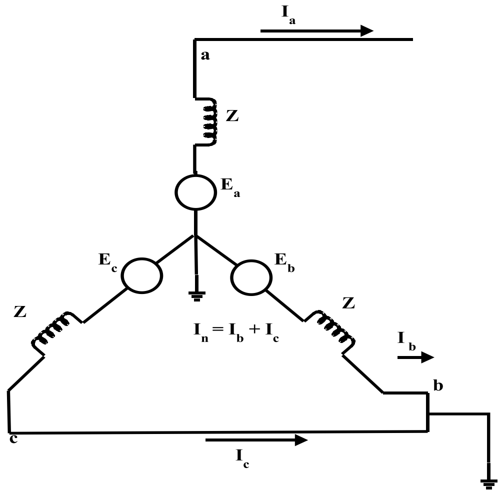

FIGURE 2.7: CIRCUIT DIAGRAM FOR LLG FAULT

As we are considering the no-load case of alternator, we can write-

$$I_a = 0 \tag{2.9}$$

$$V_a = V_b = 0 \tag{2.10}$$

$$\begin{pmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{pmatrix} = \frac{1}{3}\begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix}\begin{pmatrix} V_a \\ 0 \\ 0 \end{pmatrix}$$

$$V_{a0} = V_{a1} = V_{a2} = 1 / 3\ V_a \tag{2.11}$$

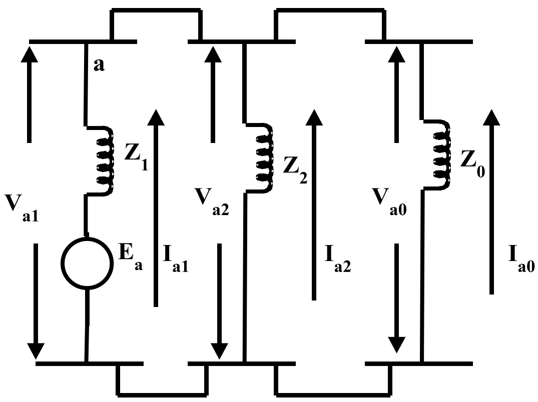

FIGURE 2.8: EQUIVALENT SEQUENCE NETWORK FOR LLG FAULT

$V_{a1} = E_a - I_{a1}Z_1$ (2.12)

$I_{a2} = -V_{a2} / Z_1$ (2.13)

$I_{a0} = -V_{a0} / Z_0$ (2.14)

By using the sequence network equation and symmetrical voltage relations we can write

$V_{a0} = V_{a1}$

$-I_{a0}Z_0 = E_a - I_{a1}Z_1$ (2.15)

$I_{a0} = -((E_a - I_{a1}Z_1)/ Z_0)$ (2.16)

Similarly

$V_{a2} = V_{a1}$

$-I_{a2}Z_2 = E_a - I_{a1}Z_1$ (2.17)

$I_{a2} = -((E_a - I_{a1}Z_1)/ Z_2)$ (2.18)

From equation (1.6) taking in terms of current we can write

$I_a = I_{a0} + I_{a1} + I_{a2} = 0$

$= (-((E_a - I_{a1}Z_1) / Z_0)) + I_{a1} + (-((E_a - I_{a1}Z_1) / Z_2))$ (2.19)

By solving the above equations we will get

$I_{a1} = E_a / (Z_1 + Z_0Z_2 / (Z_0 + Z_2))$ (2.20)

So we can conclude that in case of LLG fault all the three sequence components will be present. If it is in terms of voltages then all are equal in magnitude and if in terms of current then all are unequal. So the sequence networks should be connected in parallel as shown in Fig 2.8.

2.4 LINE TO LINE FAULT:-

If any two phases in 3-ϕ circuit get short circuited then the fault will be known as line to line (LL) fault [8]. Let the fault occurs in the phases ‘b’ and ‘c’ as shown in the Fig.2.9.

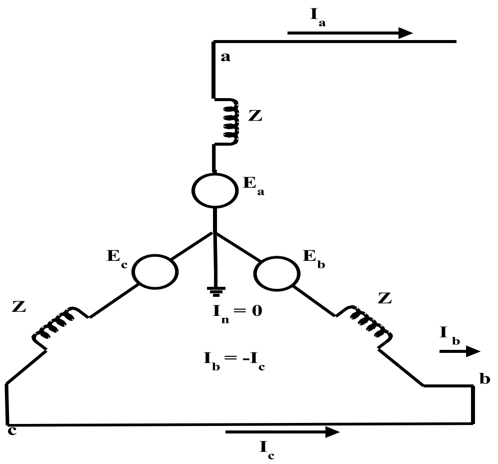

FIGURE 2.9: CONNECTION DIAGRAM FOR LL FAULT

As we are considering the no-load case of alternator, we can write-

$V_b = V_c$ (2.21)

$I_a = 0$ (2.22)

&

$I_b = I_c$ (2.23)

By putting the above conditions we can write

$$\begin{pmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix} \begin{pmatrix} 0 \\ I_b \\ I_c \end{pmatrix}$$

$I_{a1} = 1 / 3 (0 + aI_b + a^2 I_c)$ (2.24)

$= 1 / 3 (a - a^2) I_b$ (2.25)

$I_{a1} = -I_{a2} = 1 / 3 (a - a^2) I_b$ (2.26)

$I_{a0} = 0$ (2.27)

Zero sequence current is absent in this case. The positive sequence current and negative sequence current are equal in magnitude and having opposite in sign. By solving the voltage equations we can write

$V_b = V_{a0} + aV_{a1} + a^2 V_{a2}$ (2.28)

$V_c = V_{a0} + a^2 V_{a1} + aV_{a2}$ (2.29)

As it involves phase 'a' and 'b'

$V_b = V_c$

$V_{a0} + aV_{a1} + a^2V_{a2} = V_{a0} + a^2V_{a1} + aV_{a2}$ (2.30)

$(a - a^2) V_{a1} = (a - a^2) V_{a2}$ (2.31)

$V_{a1} = V_{a2}$ (2.32)

The above equations show that positive sequence components of voltages and negative sequence components of voltages will remain present and equal in magnitude. Now by using sequence network equation and equation (2.32) we can write

$V_{a1} = V_{a2}$

$E_a - I_{a1}Z_1 = -I_{a2}Z_2 = I_{a1}Z_2$

$I_{a1} = E_a / (Z_1 + Z_2)$ (2.33)

The equivalent sequence network is shown in Fig 2.10

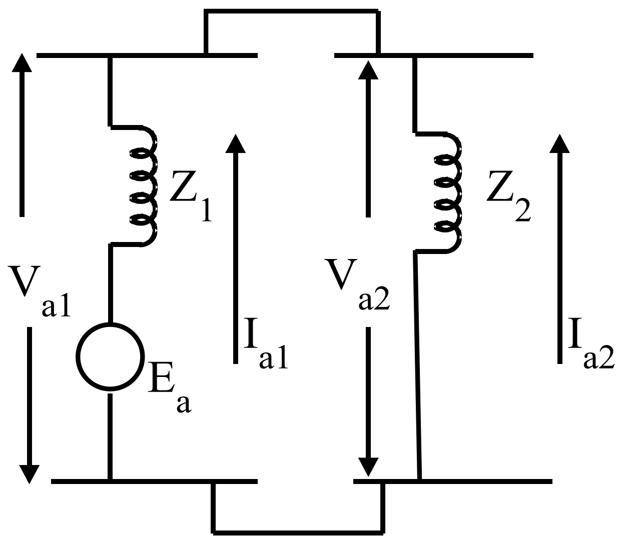

FIGURE 2.10: EQUIVALENT CIRCUIT FOR LL FAULT

2.5 THREE PHASE FAULT-

This is the type of fault where all the three phases are involved. Here all the three phases are shorted to ground or only three phases get shorted. It is the most severe fault in power system. From the Fig.2.11 we can write that:

$I_a + I_b + I_c = 0$ (2.34)

&

$V_a = V_b = V_c$ (2.35)

As $|I_a| = |I_b| = |I_c|$ and if $|I_a|$ is taken as reference

$I_b = a^2 I_a$ and $I_c = aI_a$

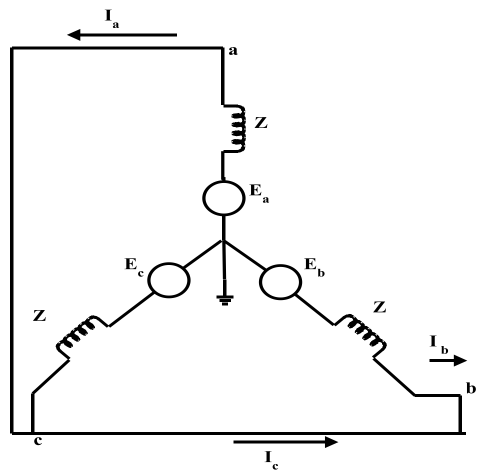

FIGURE 2.11: CIRCUIT DIAGRAM FOR THREE PHASE FAULT

Using the relation

$I_{a1} = 1/3(I_a + aI_b + a^2 I_c)$ and substituting the values of I_b and I_c

$I_{a1} = (1/3)\, 3\, I_a = I_a$ (2.36)

$I_{a2} = 1/3\,(I_a + a^2 I_b + aI_c)$ (2.37)

Substituting for I_b and I_c in terms of I_a

$I_{a2} = 1/3(I_a + a^4 I_a + a^2 I_a)$

$= 1/3(I_a + aI_a + a^2 I_a)$

$= (I_a / 3)(1 + a + a^2)$

$= 0$ (2.38)

Similarly we can write

$I_{a0} = 1 / 3(I_a + I_b + I_c) = 0$ (2.39)

So, we can say that in case of 3-ϕ fault zero sequence current and positive sequence current are absent and only positive sequence current is present. Now from the voltage equations we can write

$V_{a1} = \frac{1}{3} (V_a + aV_b + a^2V_c)$ (2.40)

$= V_a / 3 (1 + a + a^2)$

$= 0$ (2.41)

$V_{a2} = \frac{1}{3} (V_a + a^2 V_b + aV_c)$

$= V_a / 3 (1 + a + a^2)$

$= 0$ (2.42)

$V_{a0} = 0$ (2.43)

The sequence network is shown in Fig. 2.12:

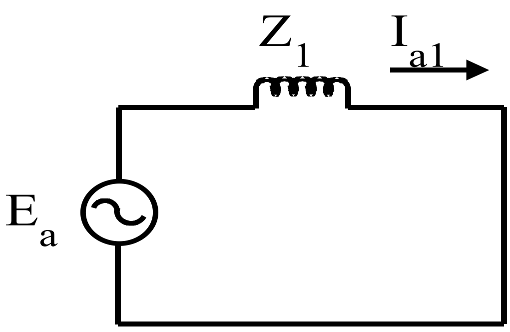

FIGURE 2.12: EQUIVALENT SEQUENCE NETWORK FOR THREE PHASE FAULT.

2.6 OBSERVATIONS:

By solving the equations (1.5-1.7) for different kinds of faults in power system we can observe the relationship between all the three sequence components (currents/voltages) as follows:

TABLE 2.1: SUMMARY OF DIFFERENT VALUES OF SYMMETRICAL VOLTAGE COMPONENTS AND THEIR RELATIONS FOR DIFFERENT TYPES OF FAULTS

Types of fault	V_{a0}	V_{a1}	V_{a2}	Additional condition
L-G	P	Q	R	$V_{a0} \neq V_{a1} \neq V_{a2}$
L-L	0	Q	R	V_{a1}=V_{a2}
L-L-G	P	Q	R	V_{a0} = V_{a1} =V_{a2}
3-ϕ	0	Q	0	V_{a0} = V_{a1} =$V_{a2} \cong 0$

TABLE 2.2: SUMMARY OF DIFFERENT VALUES OF SYMMETRICAL CURRENT COMPONENTS AND THEIR RELATIONS FOR DIFFERENT TYPES OF FAULTS

Types of fault	I_{a0}	I_{a1}	I_{a2}	Additional condition
L-G	P	Q	R	$I_{a0} = I_{a1} = I_{a2}$
L-L	0	Q	R	I_{a1} = - I_{a2}
L-L-G	P	Q	R	$I_{a0} \neq I_{a1} \neq I_{a2}$
3-ϕ	0	Q	0	$I_{a0} = I_{a2} \approx 0, I_{a1} \neq 0$

CHAPTER #3

Multisim Simulations

3.1 INTRODUCTION

NI Multisim is an electronic schematic capture and simulation program which is a part of circuit design programs, like OrCAD PSPICE. At present time it was mainly used as an educational tool to teach electronics technician and electronics engineering programs in colleges and universities. National Instruments has maintained the educational legacy, with a specific version of Multisim with features developed for teaching electrical and electronics engineering [4].

As this project is about the fault detection in three phase circuit we had developed the three phase circuit to analyse the types of fault by calculating the sequence components. The steps to be followed are:

Step 1 Generation of balanced three phase supply.

Step 2 Creation of different kind of faults using switches.

Step 3 Calculation of sequence components for unbalanced condition.

Step 4 Observation of sequence components and corresponding voltage waveform.

Step 5 Put the logic by observing the sequence components and detection of types of fault.

Generation of balanced three phase supply: The three phase supply can be obtained by using three 230V / 9V transformers are used for sensing the phase voltages (3 transformers for the three phases).

Fault Creation: Three push-button switches are connected in the three phase circuit as shown in Fig.3.6. Both symmetrical and asymmetrical can be created by pressing any one or more push-button switches at a time.

Calculation of sequence components: To calculate the sequence components for any unbalanced system we need to shift the faulty voltages/currents to $120^0$and 240^0. Then by using summer circuit the sequence components can be calculated.

Logic: From the values of various sequence components logic can be used to discriminate all types of fault.

3.2 USE OF ACTIVE ALL PASS FILTER FOR PHASE SHIFTING:

The type of filter that doesn't affect the amplitude and shifts the phase of any signal is known as all pass filter. The main purpose of this filter is to add phase shift to the response of the circuit. The amplitude of an all pass filter is same for all frequencies. There are two kinds of filter first order and second order all pass filter[9].

The transfer function of the first order all pass filter active filter will be in the form of

$$T(s) = (s - a) / (s + a) \tag{3.1}$$

The pole of this transfer function is located in the left half plane and the zero in the right half plane at equal distance from the origin on real axis. The magnitude of the numerator is identical with the magnitude of the denominator and $| T (j\omega) | = 1$ for all ω. the circuit having this characteristics is known as all pass filter (APF). The APF circuit is shown in Fig. (2) & (3) using operational amplifier can be used to obtain specified phase shift at one frequency without changing the magnitude of T (jω), even if frequency changes [9]. The phase shift θ_d produced can be obtained from equation (3.1) as

$$\begin{aligned}\theta_d &= \theta_1 - \theta_2 \\ &= \mathrm{Tan}^{-1} (-\omega_d RC) - \mathrm{Tan}^{-1} (\omega_d RC) \end{aligned} \tag{3.2}$$

Because of the nature of pole and zero locations,

$$\theta_1 + \theta_2 = 180^0 \tag{3.3}$$

From the equations (3.3) and (3.4)

$$\theta_1 = (180^0 + \theta_d) / 2 \tag{3.5}$$

Substituting the value of θ_d from equation (3.2) in equation (3.5) we get

$$\theta_1 = \text{Tan}^{-1} (\omega_d RC) \tag{3.6}$$

To obtain a phase shift of 120^0 at a frequency of 50 HZ, i.e. ω_d = 314, from equation (3.6) the values of RC is computed as RC = 0.001838.[9]

So the values calculated are R = 18.3KΩ and C = 0.1μF. If two components, i.e. R&C are inter changed, values of R&C are equal to 55KΩ and 0.1μF respectively then the phase shift of the circuit is twice, i.e. $240^{0.}$ The circuit shown in Fig.3.1 and Fig.3.2 is used to rotate the phase voltage by $120\ ^0$ and $240\ ^0$.

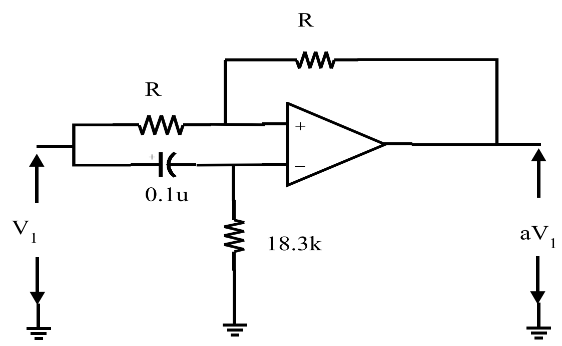

FIGURE 3.1 : ALL PASS FILTER FOR SHIFTING 120^0

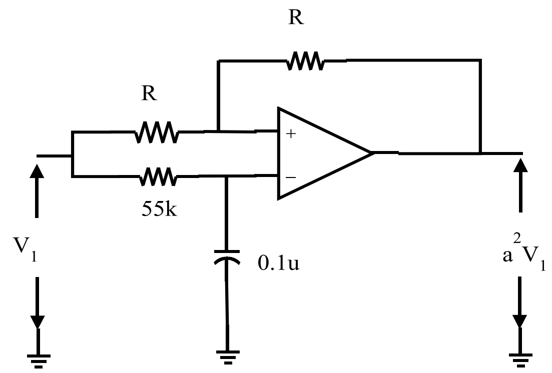

FIGURE 3.2: ALL PASS FILTER FOR SHIFTING 240^0

3.3 SUMMATION CIRCUIT FOR OBTAINING SEQUENCE COMPONENTS OF VOLTAGES:

Using the phase shifting circuits a phase shift of 120^0 or 240^0 can be obtained for voltages V_b and V_c.In order to extract the sequence components we have to sum up V_a, V_b and V_c according to the following formulas [9] :

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c) \tag{3.7}$$

$$V_{b0} = \frac{1}{3}(V_a + aV_b + a^2V_c) \tag{3.8}$$

$$V_{c0} = \frac{1}{3}(V_a + a^2 V_b + aV_c) \tag{3.9}$$

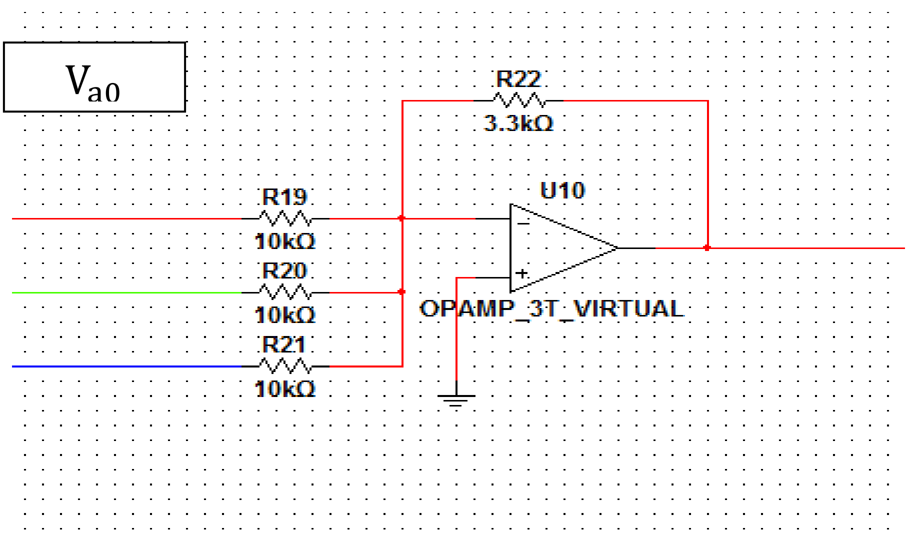

FIGURE 3.3: SUMMER CIRCUIT FOR ZERO SEQUENCE VOLTAGE COMPONENTS

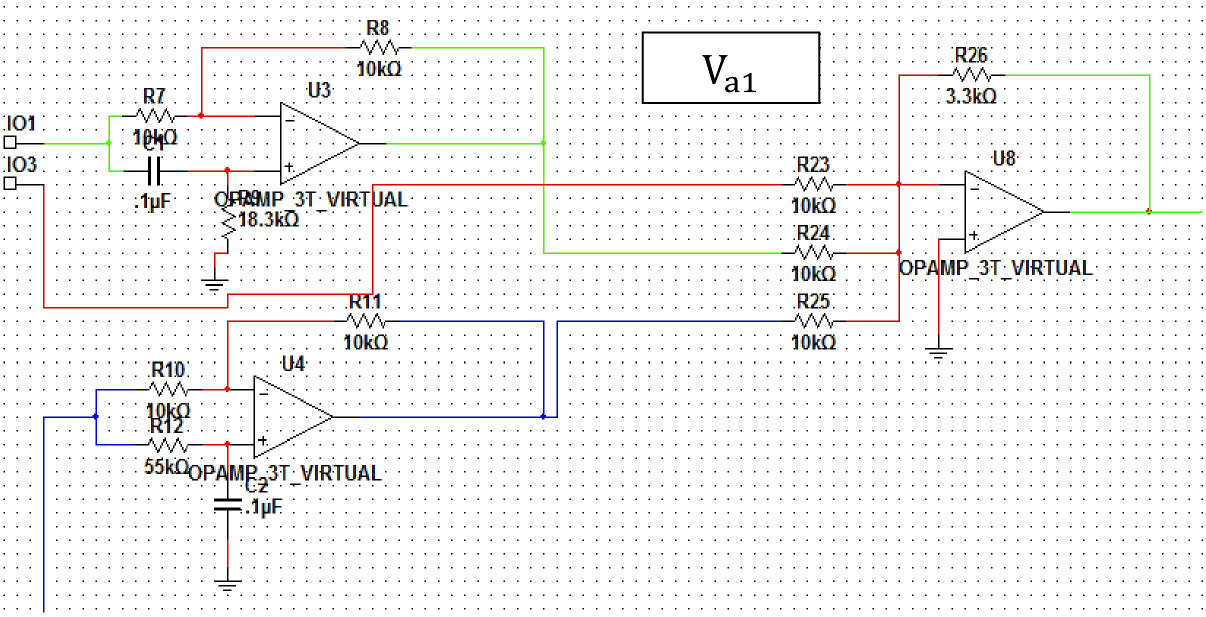

FIGURE 3.4: SUMMER CIRCUIT FOR POSITIVE SEQUENCE VOLTAGE COMPONENTS

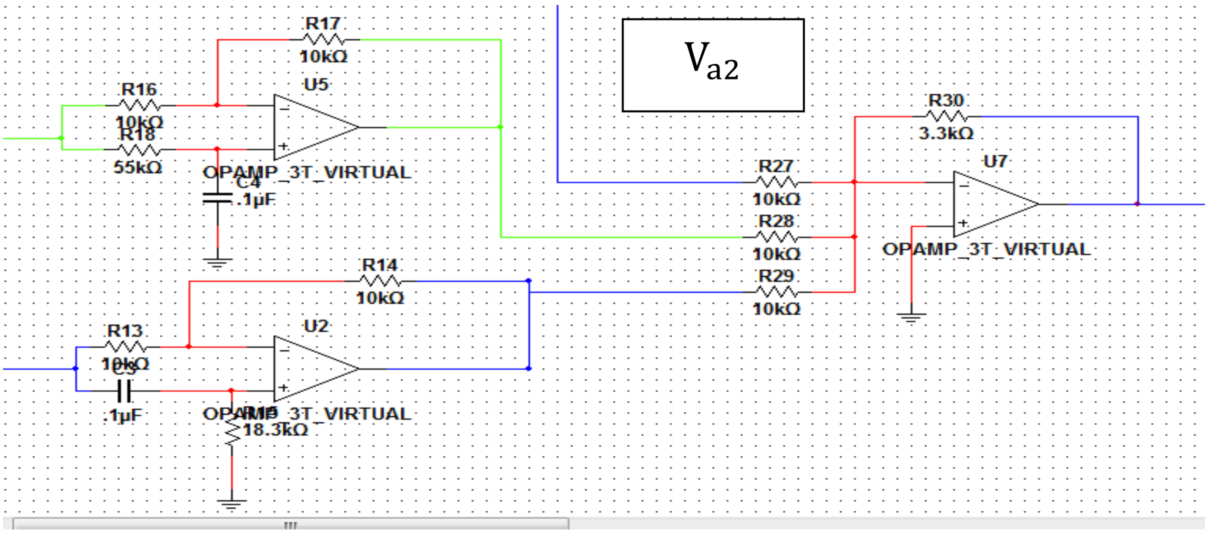

FIGURE 3.5: SUMMER CIRCUIT FOR NEGATIVE SEQUENCE VOLTAGE COMPONENTS

The complete circuit will be as shown in Fig.3.7. The sequence component voltages are then rectified and fed into the filter circuit to get a proper dc output. Now that dc outputs are compared with a constant voltage 1V by the comparator circuit. If the filtered sequence component voltage is higher than the reference voltages then the output of comparator is the offset voltage of the comparator. Now according to the comparator output for individual faults we can set up logics such that one LED will glow.

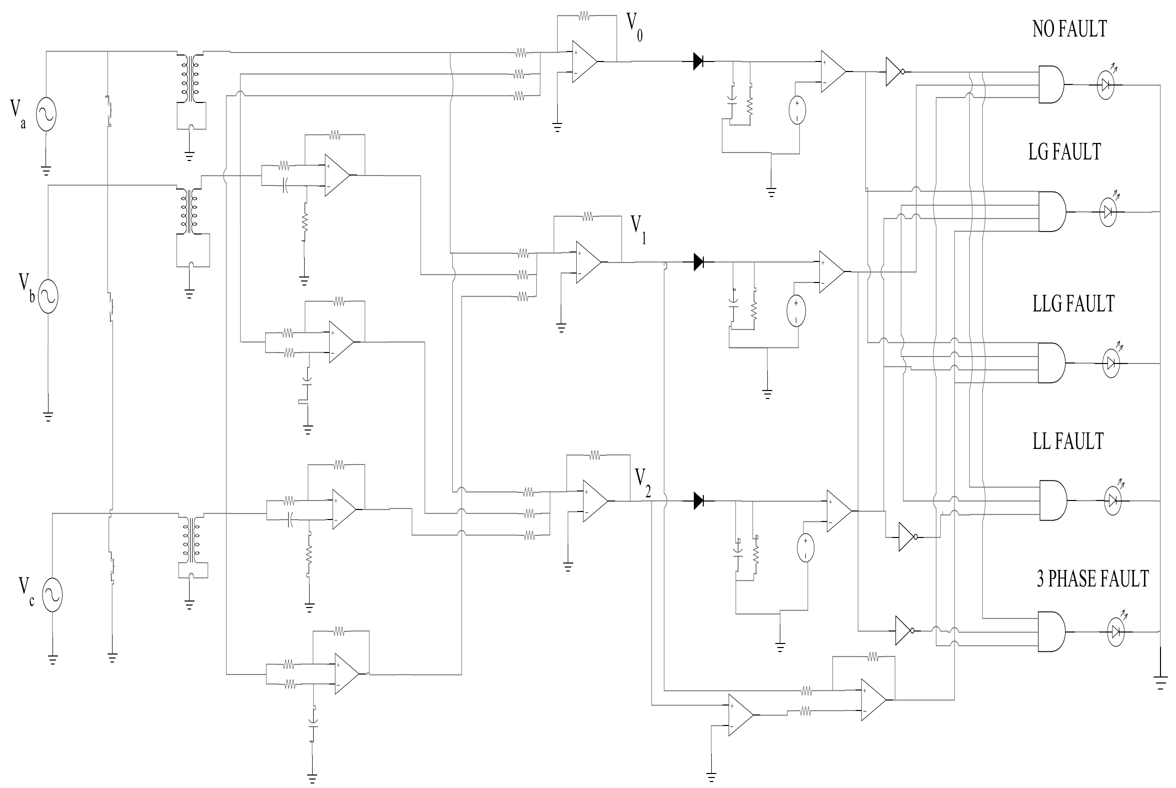

FIGURE 3.6: COMPLETE CIRCUIT FOR SIMULATION PURPOSE IN MULTISIM

3.3 SIMULATION RESULTS AND LOGIC USED:

If we take the output voltages waveforms after the summer circuit then they will look like as follows:

No fault:

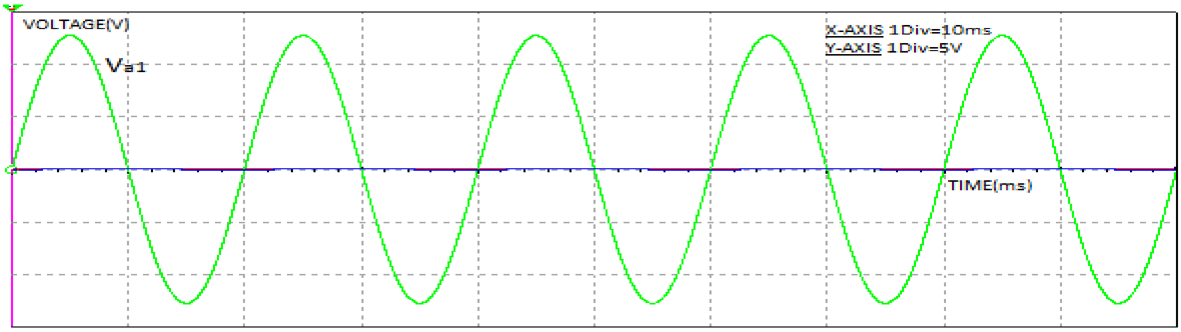

FIGURE 3.7: NO FAULT VOLTAGE-TIME WAVEFORM

The voltage waveform shows that only one sequence component is present i.e positive sequence component and negative and zero components are zero.

Single line to ground fault:-

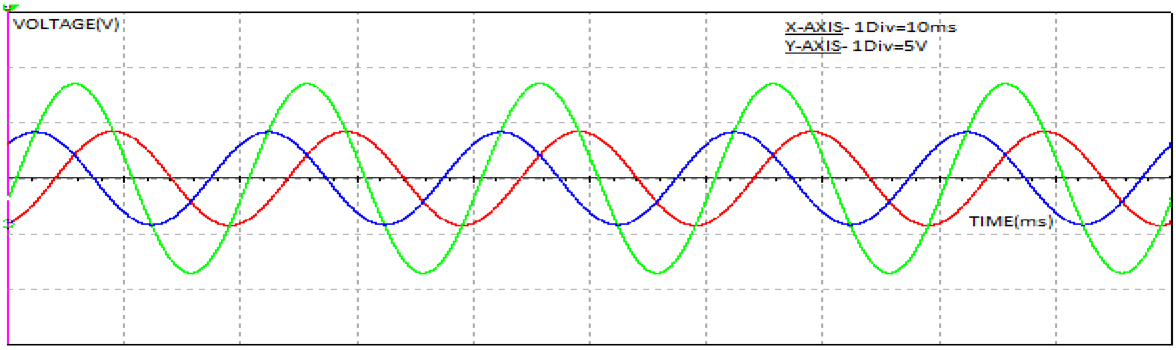

FIGURE 3.8: SINGLE LINE TO GROUND FAULT VOLTAGE-TIME WAVEFORM

The waveform shows that all the three voltage sequence components are present but their magnitudes are different.

Line to line fault:-

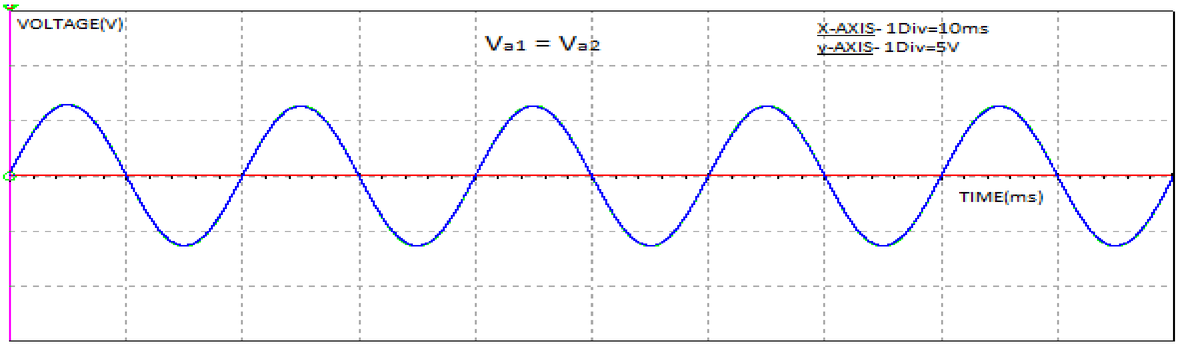

FIGURE 3.9: LINE TO LINE FAULT VOLTAGE-TIME WAVEFORM

During double line fault zero sequence components is absent both positive and negative components are present they have equal magnitudes.

Double line to ground fault:-

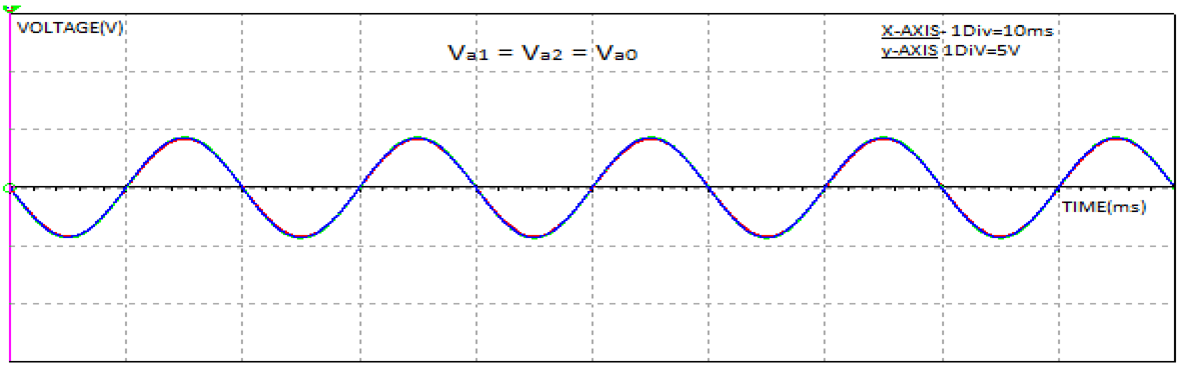

FIGURE 3.10: DOUBLE LINE TO GROUND FAULT VOLTAGE-TIME WAVEFORM

During Double Line to Ground fault all the three voltage sequence components are present and have equal magnitudes. During the three phase fault all the three sequence components will be absent.

Logics Used For Fault Detection:

No Fault: $V_{a0} = 0$, $V_{a1} = 1$, $V_{a2} = 0$, so LED will glow when $V'_{a0} \times V_{a1} \times V_{a2}' = 1$

LG: $V_{a0} = 1$, $V_{a1} = 1$, $V_{a2} = 1$, so LED will glow when $V_{a0} \times V_{a1} \times V_{a2} \times (V_{a1} - V_{a2}) = 1$

LLG: $V_{a0} = 1$, $V_{a1} = 1$, $V_{a2} = 1$, so LED will glow when $V_{a0} \times V_{a1} \times V_{a2} \times (V_{a1} - V_{a2})' = 1$

LL: $V_{a0} = 0$, $V_{a1} = 1$, $V_{a2} = 1$, so LED will glow when $V'_{a0} \times V_{a} \times V_{a2} = 1$

3Ø: $V_{a0} = 0$, $V_{a1} = 0$, $V_{a2} = 0$, so LED will glow when $V'_{a0} \times V'_{a1} \times V'_{a2} = 1$

CHAPTER #4

Virtual Instrument and Hardware Interfacing

4.1 INTRODUCTION:

The acronym LabVIEW stands for **Laboratory Virtual Instrumentation Engineering Work Bench.** Originally designed for testing and measurement applications, the program has modified over the years to design and analyse various complex systems [6]. Since **LabVIEW** is based on graphical programming, the users can build instrumentation called virtual instruments (VIs) using software objects. With proper hardware, these VI's can be used for remote data acquisition, design and analysis. [6] The built in library of Lab VIEW has a number of VIs that can be used to design and develop any system. The model we developed in the block diagram window is able to sense the voltages/currents from the hardware circuit model via USB 6009 kit. It is designed in such a manner that for any kind of fault it is capable of calculation the sequence components. Now according to the values obtained we have put the logic to discriminate the type of fault, simultaneously we can see a LED will glow in front panel window.

4.2 LABVIEW MODEL:

The main job of using LabVIEW software program in this report is to interface the real time hardware kit via tool kit USB6009.It is the only software program which facilitates the data acquisition. Here also the main job is to calculate the symmetrical current/voltage components. The building blocks that are used in LabVIEW are:

- DAQ Assistant - It acquires the data from the data from the tool kit at each time, so that we can get the real analog signal from the hardware model.
- Tone measurement- It helps in separating the frequency, amplitude and phase of the signal so that we can use them in further process.

- Basic Averaged DC-RMS – It takes the magnitude of any quantity, which may be dc or rms.
- Index Array Function – As we are acquiring the continuous signal we can store them in an array. This block always gives the first element stored in array.
- Conversion VIs- By using basic averaged dc-rms block we get the phase in degree, but for further processing we have to change them in terms of radian. So conversion VIs helps in this task.
- Trigonometric Functions- To calculate the symmetrical components we need to shift the phases of currents/voltages by an angle of 120^0 or 240^0. So the original phase is added with required phase shift and multiplied with the cosine function.
- In Range and Coerce Function- This is the block used to set the ranges of symmetrical current components values for different kinds of faults.

  Apart from above there are many VI s used in the LabVIEW model like addition, comparison, Boolean functions etc.

The mathematical calculations that used in this model is:

Let us assume that $I_a\angle\phi_1$, $I_b\angle\phi_2$, $I_c\angle\phi_3$ are the faulty current signals detected by the tool kit

Zero sequence components can be determined by:-

$$I_{a0} = [\ I_a\angle\phi_1 + I_b\angle\phi_2 + I_c\angle\phi_3\ ] / 3 \tag{4.1}$$

Positive sequence components can be determined by:-

$$I_{a1} = [\ I_a\angle\phi_1 + I_b\angle(\phi_2+120) + I_c\angle(\ \phi_3 + 240\ )\ ] / 3 \tag{4.2}$$

Negative sequence components can be determined by:-

$$I_{a2} = [\ I_a\angle\phi_1 + I_b\angle(\phi_2+240) + I_c\angle(\phi_3 + 120)\ ] / 3 \tag{4.3}$$

From the above three equations we will consider the magnitude only to put them in logic.

The complete model to determine the symmetrical components is shown in Fig. 4.1

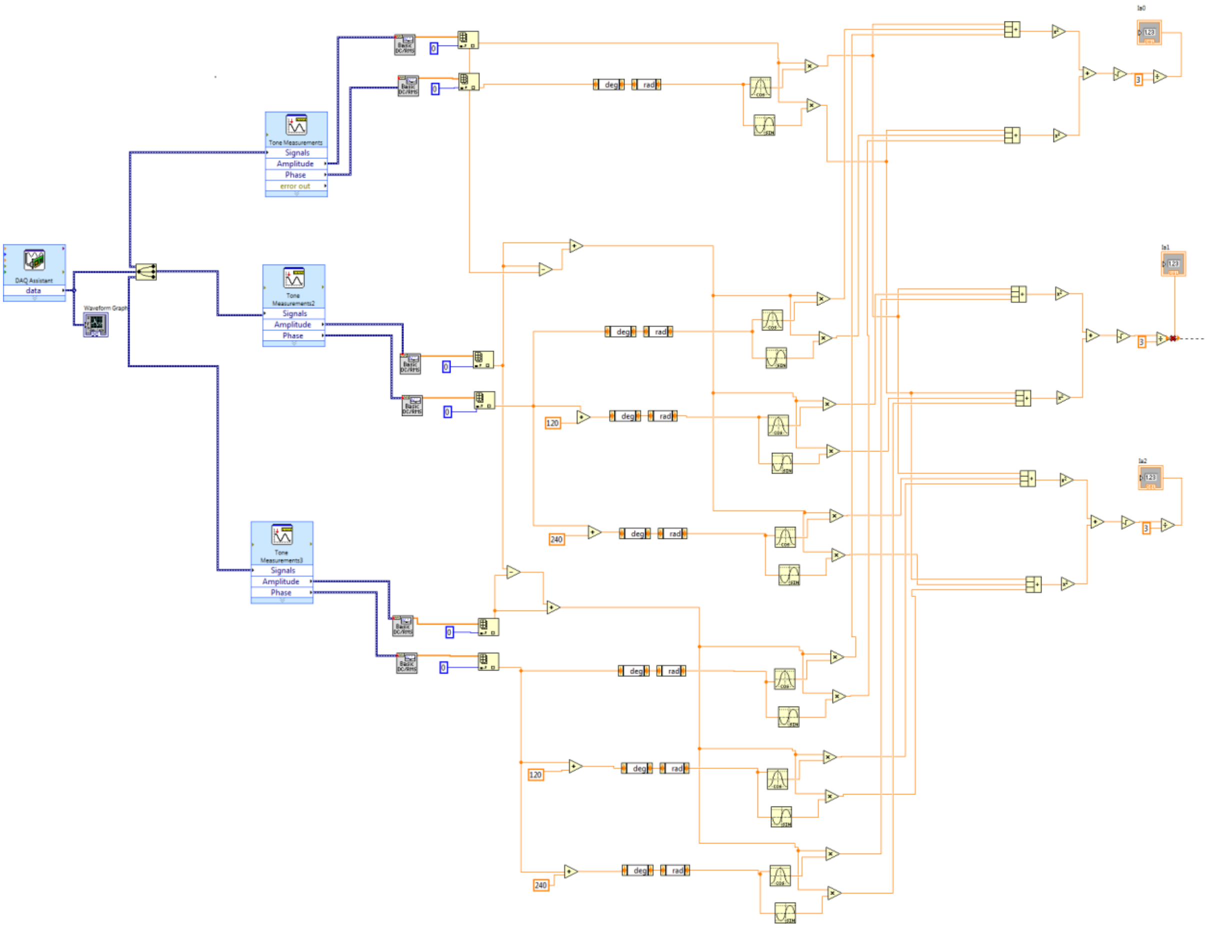

FIGURE 4.1: LABVIEW CIRCUIT TO CALCULATE SYMMETRICAL COMPONENTS

4.3 HARDWRE MODEL AND USB 6009 INTERFACING

a. *USB 6009 Tool Kit*

USB 6009 is a 8channel analog input (14 bit, 48kSa/s), 2 analog output(12bit, 150kSa/s) data acquisition (DAQ) device is compatible with LabVIEW used to interface live electrical signal to computer. USB 6009 is compact and portable so students can extend hands-on learning outside of the lab environment using industry-standard tools and methods.

b. Hardware Circuit

A small hardware circuit consists of 3 transformers (6VA, 230 / 12, 0.5A), 3 resistors (1k), 3 push button switches.

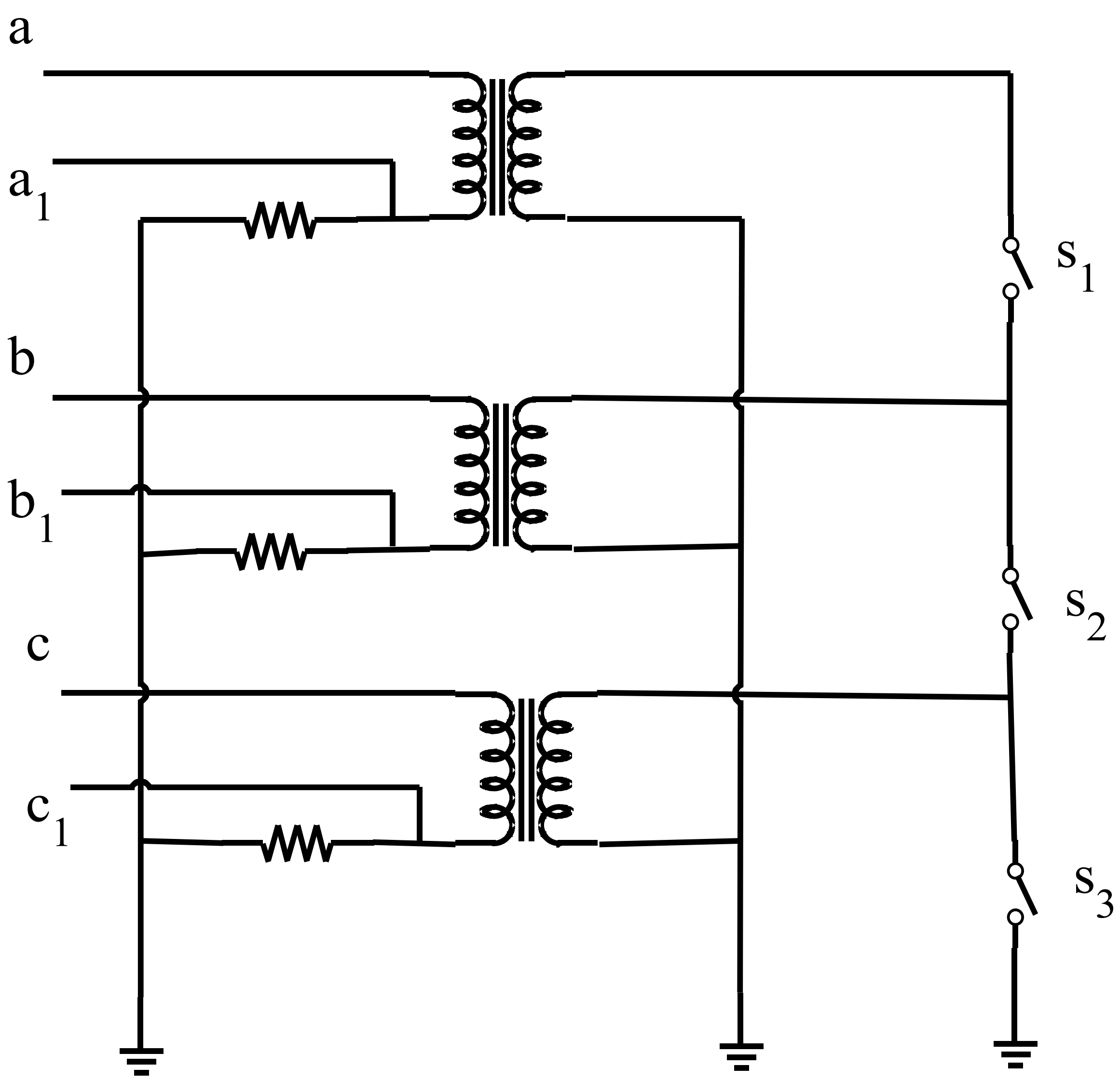

FIGURE 4.2: CIRCUIT DIAGRAM OF HARDWARE

There are three push-button connected as shown in Fig.4.2 in the secondary side of the transformers. To create any fault we need to press the push-button switches. A LG fault can be created by pressing S_3, similarly to create LL fault S_1 or S_2 can be pressed. In this way all the faults can be created in the hardware model by pressing one or more number of pushbuttons at a time. When any fault is created three will be variation in the primary side of the transformer, that variation can be treated as fault voltages/currents. Here we are detecting the currents.

4.4 LOGIC CIRCUIT AND RESULT:

After performing the entire task it has observed that the symmetrical current component varies for different kinds of fault. The particular range of any symmetrical current components for a specific fault is noted. Now for a particular voltage /power rating the range will remain same for individual faults. So if all the three symmetrical components satisfies the conditions for a particular fault a LED will glow in the front panel window of LAbVIEW. The complete logic used for a particular voltage and different types of fault is shown in Fig.4.3

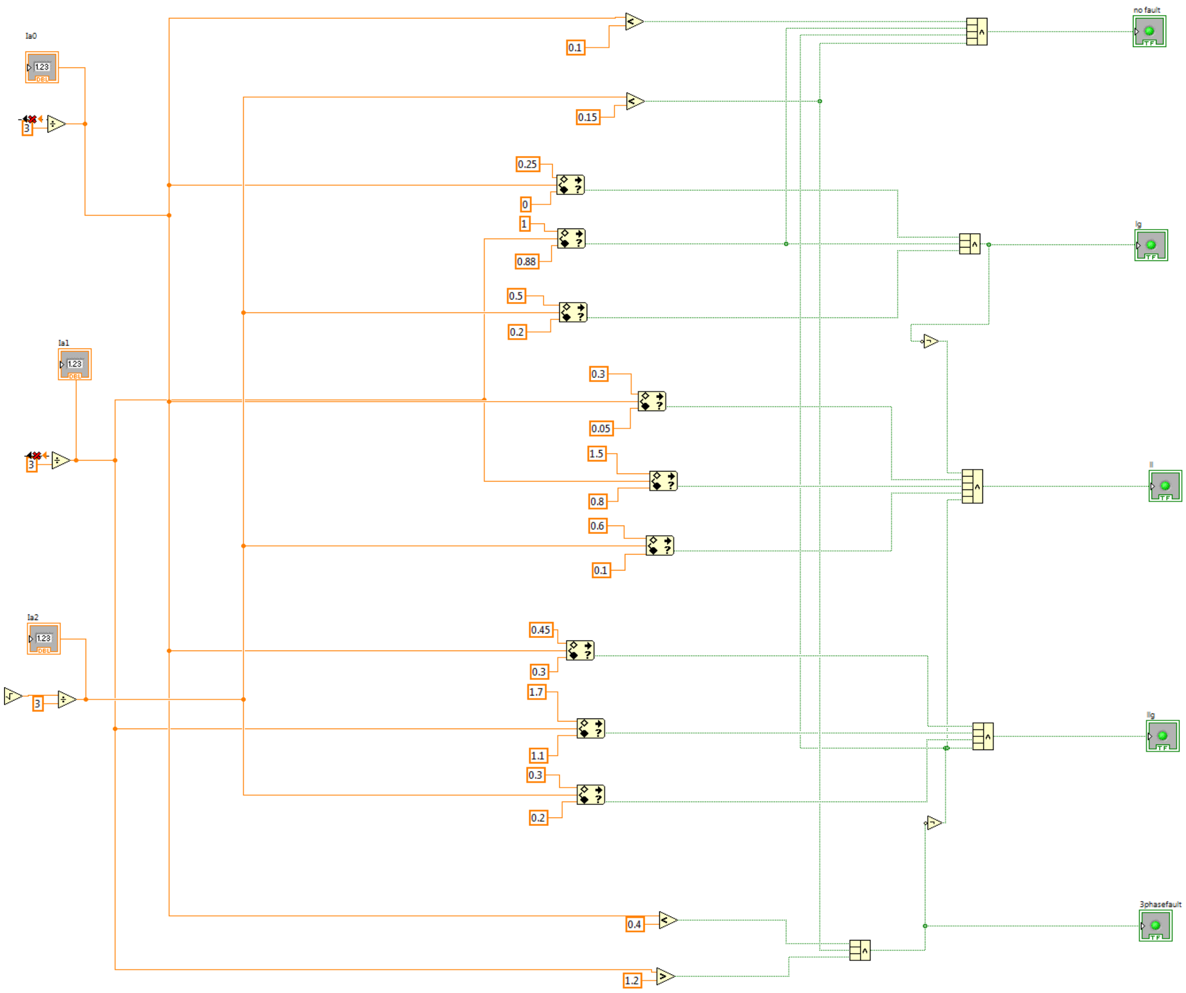

FIGURE 4.3: LOGIC CIRCUIT USED TO DETECT THE FAULT

CHAPTER #5

Conclusion And Future work

5.1 CONCLUSION

A new approach to detect the fault in three phase circuit has been presented in this paper. The total processes involved are highly concentrated on "Symmetrical Component Theory". In case of simulation work using Multisim voltage is sensed. So the symmetrical voltage components are calculated using various electrical components present in the library of Multisim. Basic requirement for calculation of symmetrical component requires phase shifting of faulty voltages/current. The operational amplifier as all pass filters is used to shift the voltages by 120^0 or 240^0. Again the op-amp as summer gave the symmetrical voltage components. We are concentrated only on the magnitude of symmetrical components, the output of summer circuit passed through a filter circuit. The comparator circuit used after filter circuit gave either high or low output, which facilitated to use the Boolean logic to detect different kinds of fault.

As far as virtual instruments and hardware interfacing is concerned symmetrical current components is sensed. The hardware model provided the faulty three phase supply for different kinds of fault using three switches. The tool kit USB 6009 used to interface the hardware with LabVIEW. Now the faulty current is acquired by the DAQ assistant virtual instrument block and the model designed in LabVIEW calculate the symmetrical components. The range of each symmetrical component varied for each type of fault. That range provides either high or low output, which has been used to discriminate the faults from each other.

5.2 FUTURE WORK

This report is solely associated with shunt faults in the power system. We designed the simulated and hardware model to detect the fault using the symmetrical component's magnitude only. The series fault in power system can also be detected by certain modifications and addition in circuit. Not only the voltage/current magnitude varies during the fault in power system but there are other factors like frequency, harmonic content, and temperature also get changed. So development of this project may leads towards the reliable fault detection techniques in power system. As far is severity of fault is concerned we should be aware of level of severity for the protection of switchgear equipment, so severity analysis can be treated as an important extension of this report.

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